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A LONGITUDINAL STUDY OF RESTING ENERGY EXPENDITURE IN THERMALLY INJURED PATIENTS

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We have recently developed a new burn-specific equation that satisfactorily estimates initial caloric requirements for thermally injured patients. In the present study, we compared these estimates with resting energy expenditures (REE) (n = 141) measured weekly by indirect calorimetry in 20 patients between postburn days 3 and 348. In this group, mean initial burn size was 46.7% (range, 21–88) and mean age 31.3 years (range, 19–61). Serial measurements were continued until the burn wounds were closed or the patient was discharged. Multiple regression analysis indicated a relationship between REE, initial burn size, and postburn day in these patients (r = 0.65). This analysis indicated a general trend of decline in REE toward normal values 100 to 150 days postburn in patients with smaller burns (20%–40%) and roughly 250 days postinjury in those with larger burns (>75%). The initial predictive equation appeared adequate for estimating caloric needs during the first postburn month, but beyond 30 days postburn indirect calorimetric measurements became necessary for accurate estimation of caloric requirements.

THE HYPERMETABOLIC response to severe thermal injury includes a marked increase in oxygen consumption and caloric requirement. The energy requirement during the early postburn peak of hypermetabolism can be estimated by using any of several recently derived burn-specific formulas or by indirect calorimetric measurement.[1–3] Although recent studies have indicated some decrease in peak metabolic requirements of burn patients, few longitudinal studies have been conducted to examine the time course over which the metabolic requirement returns to normal.

We have recently revised the equation used for predicting initial caloric requirements in our burn patients.[1,4] Unlike the former curvilinear equation, the revised equation is linear; resting energy expenditure (REE) is directly correlated with burn size in non-intubated patients (r = 0.724). The objective of the present study was to determine whether caloric needs later in the hospital course can be predicted on the basis of wound closure, postburn day, or both.

MATERIALS AND METHODS

Twenty patients admitted to the United States Army Institute of Surgical Research were enrolled in a longitudinal study assessing changes in metabolic rate during their hospital course. Resting energy expenditure was measured by indirect calorimetry using a DeltaTrac (Sensormedics, Anaheim, Calif) metabolic cart. Only non-intubated patients with burns of more than 20% of the total body surface were studied. Twenty-four-hour urine collections were obtained from patients with indwelling urinary catheters to measure urinary urea nitrogen excretion on each study day. Metabolic studies were performed at scheduled intervals at 6:00 AM, while the patient was at rest. The studies were performed at bedside in order to assess metabolic rate under the usual clinical conditions. Metabolic studies were accepted when the standard deviations of V_{CO_2}, V_{O_2}, RQ, and REE measurements were less than 10% of their respective means. Oral feedings were discontinued for 6 hours prior to the studies, but enteral feedings via nasojejunal tubes were continued in some patients. Metabolic studies were performed at least 48 hours after any surgical procedure falling within the study period. The percentage of the total body surface occupied by unhealed burn wound was estimated by the attending physician. Studies were performed weekly until the burn wound was closed or the patient discharged. All study protocols were accepted by the U.S. Army Institute of Surgical Research Human Use Committee and adhered to the provisions of established regulatory guidelines concerning experimentation involving humans.

Predicted resting energy expenditure was based on an equation recently derived for acutely burned patients[1]:

$$\text{Predicted REE (kcal/m}^2\text{/hr)} = (\text{BMR}*(0.89142 + (0.01335*\text{TBSB})))$$

Basal metabolic rate (BMR) was estimated using the Fleisch formula for non-injured humans.[5] Resting energy expenditure (REE) was measured by indirect calorimetry under resting conditions; in normal individuals, this value is expected to be approximately 10% greater than basal metabolic rate.

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Multiple regression analysis was used to relate the ratio of measured REE: predicted REE to postburn day and percentage open wound and to explore the relationship between REE and body surface area, initial percentage of burn, percentage of open wound, and postburn day.

RESULTS

Demographic and metabolic rate data are summarized in Tables 1 and 2. One hundred forty-one metabolic studies were performed in 20 burned patients who did not require tracheal intubation. Mean age and burn size in this group were 31.3 years and 46.7%, respectively. The mean estimated BMR was 36.7 kcal/m^2/h. At the time of discharge, the mean measured REE was 46.7 kcal/m^2/h.

Over the entire range of postburn days, the ratio of measured REE to predicted REE (MREE:PREE) was inversely correlated with postburn day ($r = -0.738$, $p < 0.001$). This ratio was directly correlated with urinary urea nitrogen excretion ($r = 0.555$, $p < 0.001$), but not significantly correlated with percentage of open wound ($r = 0.052$, $p = 0.542$). A small but significant linear correlation was found between MREE:PREE and initial burn size ($r = 0.331$, $p < 0.001$).

The mean measured REE of 59.4 kcal/m^2/h was similar to the mean predicted REE of 53.5 kcal/m^2/h during the first 30 postburn days. Unlike the overall measurements, where a linear relationship was observed between the MREE:PREE and postburn day, there was little correlation with postburn day during this interval ($r = -0.254$, $p = 0.072$). Also absent during this time was any significant correlation between the ratio and urinary urea nitrogen excretion ($r = -0.121$, $p = 0.577$), while a stronger correlation was observed between measured REE and initial burn size ($r = 0.587$, $p < 0.001$).

Beyond 30 days postinjury, significant linear correlations were observed between the ratio of measured REE to predicted REE and postburn day ($r = -0.673$, $p < 0.001$) and urinary urea nitrogen excretion ($r = 0.667$, $p < 0.001$). Like the overall measurements and the measurements taken during the first 30 days, the correlation between this ratio and percentage of open wound was weak ($r = 0.087$, $p < 0.001$). A weak but significant correlation was observed between measured REE and initial burn size ($r = 0.454$, $p < 0.001$).

The ratio of measured REE to normal BMR (MREE: BMR) was found to be a function of initial burn size, decreasing exponentially with time postinjury. Figure 1 is a graphic representation of the relationship of the fractional increase in metabolic rate ((REE-BMR)/BMR) to postburn day and initial burn size, reflecting the increase in metabolic rate attributable to burn size and the decrement of the initial rate with time postburn.

The mean metabolic rate did not reach normal by the time of discharge in these patients. The fractional increase in metabolic rate after injury was proportional to burn size; the rates of decline with postburn time were similar for burns of all sizes. The extrapolated estimates of the time required to reach a normal metabolic rate therefore increased linearly with burn size, being 125–150 days for burns of 30%–40% and 200–

Table 1
Patient demographics

Patient Number	Age (years)	Sex	%TBSA Burned	BSA (m^2)	PREE (cal/m^2/h)
1	20	M	50.5	2.10	75.8
2	35	M	48	1.72	68.9
3	53	M	47	1.86	71.6
4	30	F	38	1.28	58.5
5	19	M	21	2.04	57.1
6	27	M	88.25	1.91	96.3
7	25	M	75.5	2.00	78.9
8	56	M	27.5	1.75	55.4
9	32	M	34	1.78	61.1
10	35	M	29	2.23	57.7
11	26	F	84.3	2.02	87.7
12	61	M	25.8	1.97	54.3
13	23	M	30	1.84	61.3
14	28	M	41.5	2.10	65.8
15	26	M	32.25	1.82	61.4
16	29	M	38.25	1.88	64.1
17	24	F	75	1.68	82.2
18	33	M	37	2.26	62.4
19	20	M	66	1.78	86.3
20	24	F	44.5	1.62	64.4
Mean	31.3	16M/4F	46.7	1.87	68.5

BSA = body surface area; PREE = initial predicted resting energy expenditure.

Table 2
Metabolic data

Patient Number	Discharge BSA (m^2)	Discharge MREE (cal/m^2/h)	BMR
1	2.00	48.9	38.6
2	1.65	48.1	36.5
3	1.93	43.1	36.2
4	1.29	45.9	35.1
5	2.00	49.6	39.2
6	1.69	68.0	37.5
7	1.55	49.3	37.5
8	1.74	47.8	35.4
9	1.77	45.5	36.8
10	2.09	54.6	36.5
11	1.58	44.5	35.2
12	1.93	43.4	34.9
13	1.79	36.3	38.0
14	2.10	45.2	37.1
15	1.77	48.3	37.5
16	1.82	39.1	36.8
17	1.67	42.4	35.2
18	2.14	43.5	36.7
19	1.71	46.2	38.6
20	1.64	44.3	35.6
Mean	1.80	46.7	36.7

BSA = body surface area; MREE = measured resting energy expenditure; BMR = basal metabolic rate.

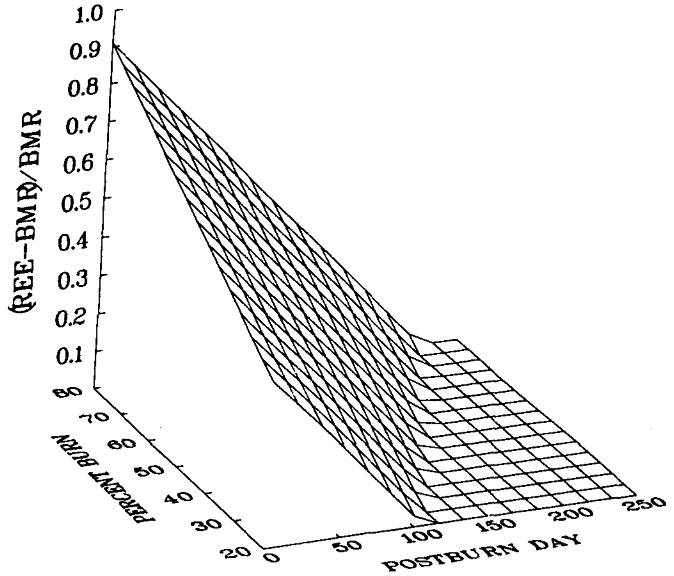

Figure 1. Relationship of the fractional increase in metabolic rate to postburn day and initial burn size.

225 days for larger (70%–80%) injuries. The regression equation describing this general trend ($r = 0.65$) is:

$$REE = BMR*(.274 + .0079*TBSB - .004*PBD) + BMR$$

Where REE, BMR = kcal/m^2/hr, and TBSB = % of total body surface burned.

Only about 40% of the variance in metabolic rate is accounted for by this formula; attempts to improve this fit by the addition of other variables were unsuccessful.

DISCUSSION

The present study confirms our previous observation[1] of linear correlation between MREE and initial burn size during the first 30 days postburn. Turner and colleagues[6] reported poor correlation between measured energy expenditure and initial burn size, but that study included measurements taken as much as 60 days postburn. In the present data, this correlation was also poor if measurements were included without respect to the postburn time at which they were acquired. In searching for a suitable method for predicting MREE beyond 30 days postburn, we have explored its relationship with postburn day and the size of the remaining open wound.

Like others,[7,8] we found no simple relationship between MREE and wound closure; a lack of correlation possibly attributable, in part, to individual variations in wound healing. We did find a linear correlation between MREE and urinary urea nitrogen excretion, validating the common belief that protein catabolism is closely related to the magnitude of hypermetabolism. This observation differs from that reported by Ireton-Jones et al.,[7] who found no significant correlation between urinary urea nitrogen excretion and measured energy expenditure. This discrepancy may be the result of differences in the design of the studies; in the earlier studies, MREE was measured at varying times of day and within 24 hours of surgical procedures. To minimize circadian effects and the effects of surgery, we performed indirect calorimetry at the same time of day, and at least 48 hours following surgical procedures. A recent study found, in a small sample of healthy people, that total energy expenditure as measured by the doubly labelled water technique was not influenced by feeding within 30 minutes of the time of measurement.[9] The potential effect of the specific dynamic action of feedings would be further minimized in hypermetabolic burn patients and appears to have been the case in the patients in this study who received enteral feedings via nasojejunal tube during the measurement periods.

We found MREE to be 25% above estimated normal BMR at the time of discharge, a time when all wounds were closed. Matsuda et al.[10] and Saffle et al.[11] reported similar findings. The MREE was typically 10% above BMR under the conditions of measurement used here, and the additional 15% could well be a result of wound healing processes and hormonal variations that continue even after wound closure.

Regression analysis indicates that the ratio MREE: BMR is related to initial burn size and postburn day, but not to the extent of residual open wound. The rate of decrease in hypermetabolism is similar for all burn sizes and is relatively modest over the first 30 days compared with thereafter. The REE can be adequately predicted on the basis of BMR and burn size during the first month postburn, and such calculations can be used to estimate the desired level of nutritional support.

The equation incorporating initial burn size and postburn day for estimating REE beyond 30 days is a weak predictor, which accounts for only 40% of the variance and has limited clinical utility. Consequently, beyond 30 days estimation of caloric requirement is best made by indirect calorimetry. Activity level must be considered in tailoring a nutritional regimen to measured REE; we usually add 25% to measured REE to estimate total caloric needs. That activity level factor is varied according to the observed activity level of the patient. Most patients will require increased caloric intake until and even beyond the time of discharge. Nutritional support efforts, which should focus on preserving and restoring lean body mass rather than increasing the fat mass that may result from overfeeding, can be guided by the results of this study.

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